

NARROW-LEAF LUPIN AS AN ALTERNATIVE CROP FOR PACIFIC NORTHWEST DRYLAND AGRICULTURE

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Introduction

Since the first alkaloid-free narrow-leaf lupin variety (*L. angustifolius*, var. Uniwhite) was introduced as a crop in Western Australia in 1967 (Gladstones et al. 1998), narrow-leaf lupin has become a major grain legume in Western Australia. The Grain Pool of Western Australia is currently exporting 500,000 to 850,000 tons of lupin grain annually, and supplying 6,000 to 7,000 tons to domestic feed lots (Garlinge et al. 2000). The Australian Sweet Lupin has been successfully exported to northern Europe, Japan, Korea, Southeast Asia, the Middle East, and southern Africa.

Narrow-leaf lupin grain contains high levels of protein and energy, is low in fat, and has good protein quality and fiber digestibility. Lupin grain can be fed directly to dairy cattle, lambs, and poultry without heat treatment, and can also be used for human consumption (Gladstones et al. 1998).

Narrow-leaf lupin is adapted to coarse-textured, relatively infertile, acid soils. It has been successfully grown in regions with rainfall from 12 to 30 inches in Western Australia (Garlinge et al. 2000). It is relatively new to the growers in the Pacific Northwest of the United States. With a dairy industry moving into eastern Oregon, nitrogen prices increasing, and the demands of growers for rotation crops for annual cropping, this legume may provide another choice for the growers in the region. However, additional research on variety selection, seeding date, seeding rate, tillage,

and weed and disease control is required before this crop is adapted to this area.

Materials and Methods

Since 1998, trials have been carried out at several locations in eastern Oregon to test varieties, seeding date, seeding rate, weed control, and water use of narrow-leaf lupins.

Variety Evaluation Trials in 1998 and 1999

Four public narrow-leaf lupin varieties (Merrit, Yorrel, Chittick, and Danja) were planted at the Pendleton Station and Sherman Station (Moro) of the Columbia Basin Agricultural Research Center (CBARC) in 1998 and 1999. The narrow-leaf lupin varieties were annual-cropped following winter wheat. The soil is classified as Walla Walla silt loam (coarse, silty, mixed mesic Typic Haploxeroll) at both locations. The plots were conventionally tilled using a moldboard plow followed by disking and rod weeding. The experiment was a completely randomized block design with a plot size of 5 ft x 20 ft replicated four times. Lupin seeds were inoculated with *Bradyrhizobium* and seeded using a Hege plot drill, equipped with double-disk openers with 12-in row spacing at a rate of 8 seeds/ft². Starter was placed with the seed at a rate of 100 lb/acre in the form of (N-P₂O₅-K₂O-S = 16-20-00-14). In 1998, seeding dates were 27 April at the Moro site and 28 April at the Pendleton site. In 1999, seeding dates were 30 March at Pendleton and 1 April at Moro. Preplanting herbicide, Sonalan E.C., was applied with a hand-held sprayer at a rate of

3/4 lb a.i./acre and incorporated to a 3-in depth. Preemergence herbicide, Sencor DF, was also applied with a plot sprayer at a rate of 4 oz/acre of product immediately after planting.

On-farm Variety, Seeding Date and Seeding Rate Trials in 1999

Four private varieties, Belara, Kalya, Tallerack, and Tanjil and one public variety, Merrit, were seeded at three locations in Oregon on three dates and at three seeding rates. The three experiment sites were Helix (Umatilla Co., 16 in rainfall), Lexington (Morrow Co., 10 in rainfall), and Condon (Gilliam Co., 12 in rainfall), the soils at the three sites are silt loam. The lupin varieties were annual-cropped following winter wheat, using direct seeding. Plot size was 10 ft x 100 ft with four completely randomized replications. A John Deere 1560 direct seeding drill, equipped with single disk openers spaced 7 in apart, was used to seed the lupins. Seeding rates were 100, 150, and 200 lb/acre on three seeding dates from early April to early May (Table 1). Lupin seeds were inoculated with *Bradyrhizobium* inoculant. Starter fertilizer was applied at a rate of 15 lb N, 10 lb P, and 18 lb S per acre, using a 1:1 mix of ammonium polyphosphate and Thiosol solutions that was banded by the drill. Prior to seeding, herbicide Sonalan 10G was spread with a Gandy spreader at a rate of 7.5 lb/acre of product. Immediately after planting, herbicide Sencor DF was sprayed with a plot sprayer at 4 oz/acre of product. Lupin grain was harvested with a 5-ft-wide Hege plot combine. Due to the lack of precipitation, lupin stems were short at Lexington and Condon sites and we experienced difficulty harvesting with a plot combine; therefore, we also harvested bundle samples by hand from a 10-ft² area.

Seeding Date Effects on Yield, Seed Quality, and Water Use Trial in 2000

Two varieties, Merrit and Kalya, were seeded at CBARC in Pendleton. Plot size was 10 ft x 70 ft with four completely randomized replications. The lupin plots were direct-seeded, following winter wheat, in an annual-crop system, using a John Deere 1560 drill equipped with single disk openers and 7-in row spaces. Lupins were seeded at a rate of 150 lb/acre on three dates in the spring of 2000 (21 and 31 March, and 17 April). Prior to seeding, lupin seeds were inoculated with a *Bradyrhizobium* inoculant slurry. Starter fertilizer was banded between the seed rows at a rate of 15 lb N, 10 lb P, and 18 lb S per acre with a 1:1 mix of ammonium polyphosphate and Thiosol solutions. Preplanting herbicide, Sonalan 10G, was spread with a Gandy spreader at a rate of 7.5 lb/acre of product. Preemergence herbicide, Sencor DF, was sprayed with a plot sprayer at a rate of 4 oz/acre of product immediately after planting. One neutron probe access tube was installed at the center of each plot, and soil water content was measured periodically using a CPN 503DR neutron probe (CPN Corporation, Pacheco, CA). Lupin grain was harvested with a 5-ft-wide plot combine. Crude protein content in lupin grain was determined by measuring N content and multiplied by a factor of 6.25.

Weed Control Experiment in 1999 and 2000

In 1999 and 2000, studies were initiated to evaluate preplant (PP) and preemergence (PRE) herbicides for general weed control in direct-seeded narrow-leaf lupin. Plots were seeded with Merrit lupin on 30 and 22 April, 1999, at Condon and Lexington, respectively, and on 21 March 2000 at CBARC in Pendleton. Soils at all sites are silt loam.

All treatments were applied with a hand-held boom with 15 gal/acre water at 30 psi spray pressure. Treatments were surface-applied either PP or PRE with no incorporation to minimize disturbance in the direct seed system (Tables 3 and 4). Plots were 10 ft by 30 ft in size, and arranged as a randomized complete block design with four replications. Plots were seeded with the John Deere 1560 drill at a rate of 150 lb/acre. Plots were evaluated for visible lupin injury and weed control. Dry seed yield estimates were obtained by harvesting the standing crop with a plot combine.

Results and Discussion

Variety Evaluation Trials in 1998 and 1999

Yield of lupin varied greatly among the varieties in 1998. Merrit performed the best, yielding 779 lb/acre at Pendleton and 1,237 lb/acre at Moro (Table 1). Chittick produced little grain at both Pendleton and Moro sites in 1998, even though it was observed that the Chittick had good emergence and vegetative growth. In the 1999 trials, however, all four varieties performed very well, yielding over 1,100 lb/acre at both Pendleton and Moro sites

(Table 1). Chittick and Yorrel yields were similar to those of other varieties at Moro, but they out-yielded Merrit at Pendleton. For early seeding in 1999, all the varieties performed similarly at Moro, but the late maturing variety, Chittick, yielded higher than the early maturing variety, Merrit, at the higher rainfall site in Pendleton. In contrast, with a delayed seeding date in 1998, the early maturing variety Merrit yielded higher than the late maturing variety Chittick (Table 1).

On-farm Variety, Seeding Date, and Seeding Rate Trials in 1999

All five varieties yielded over 700 lb/acre at the Helix site (16-in rainfall zone) for the earliest seeding date. Kalya had the highest yield (994 lb/acre) and Tallerack had the lowest yield (705 lb/acre; Table 2). Yield decreased dramatically with delayed sowing for all varieties, particularly Tallerack. For the second and third seeding dates, there were no significant differences among varieties except for Tallerack, which yielded the least. When seeding date was later than 10 May, none of the varieties yielded over 520 lb/acre.

Table 1. Yield of lupin at Pendleton and Moro, Oregon, sites in 1998 and 1999.

	1998		1999	
	Pendleton (Seeded on 4/28)	Moro (Seeded on 4/27)	Pendleton (Seeded on 3/30)	Moro (Seeded on 4/1)
	----- lb/acre -----	-----	----- lb/acre -----	-----
Merrit	779 a [†]	1237 a	1220 b	1162 a
Yorrel	488 b	702 b	1581 a	1132 a
Chittick	1 d	32 c	1613 a	1313 a
Danja	303 c	569 b	1381 ab	1250 a

[†] Means in the same column followed by the same letter are not significantly different according to the LSD (P = 0.05).

Due to the extreme drought during the spring of 1999, lupin did not yield well (Table 2) in the lower rainfall sites at Lexington (10-in rainfall zone) and Condon (12-in rainfall zone). Actual rainfall was not recorded at these two sites, but the rainfall received in 1999 was much less than normal years (Chen, personal communication with growers). Yields calculated from bundle samples are shown in parentheses in Table 2. Similar to the results at the Helix site, Tallerack yielded the least and Belara

performed slightly better than other varieties.

Yield response of Belara to seeding rate at the Helix site is shown in Figure 1. The yield was found relatively higher at the intermediate seeding rate of 150 lb/acre for the 2 and 23 April seeding dates. But the difference among the seeding rates was not statistically significant. Similar results were observed for other varieties at the Helix and other sites (data not shown).

Table 2. Yield of lupin at Helix, Lexington, and Condon, Oregon, in 1999.

	Seeding date	Variety				
		Merrit	Belara	Kalya	Tallerack	Tanjil
		----- lb/acre -----				
Helix (16-in rainfall zone)	4/2	764 cd [†]	951 bc	994 a	705 d	851 bcd
	4/23	627 ab	783 a	620 ab	484 b	581 ab
	5/10	517 a	485 a	466 a	256 b	480 a
Lexington (10-in rainfall zone)	3/31	157 (439 [‡]) a	137 (433) a	189 (431) a	86 (160) b	166 (480) a
	4/20	-- (70.5)	-- (146)	-- (102)	-- (16)	-- (181)
	5/8	0	0	0	0	0
Condon (12-in rainfall zone)	4/8	295 (549) ab	300 (761) a	315 (551) ab	125 (242) b	425 (617) a
	4/29	145 (196)	165 (251)	175 (150)	70 (60)	100 (202)
	5/14	0	0	0	0	0

[†] Means in the same row followed by the same letter did not significantly differ according to the LSD (P = 0.05).

[‡] Data in parentheses are yields determined from bundle samples collected from a 10-ft² area.

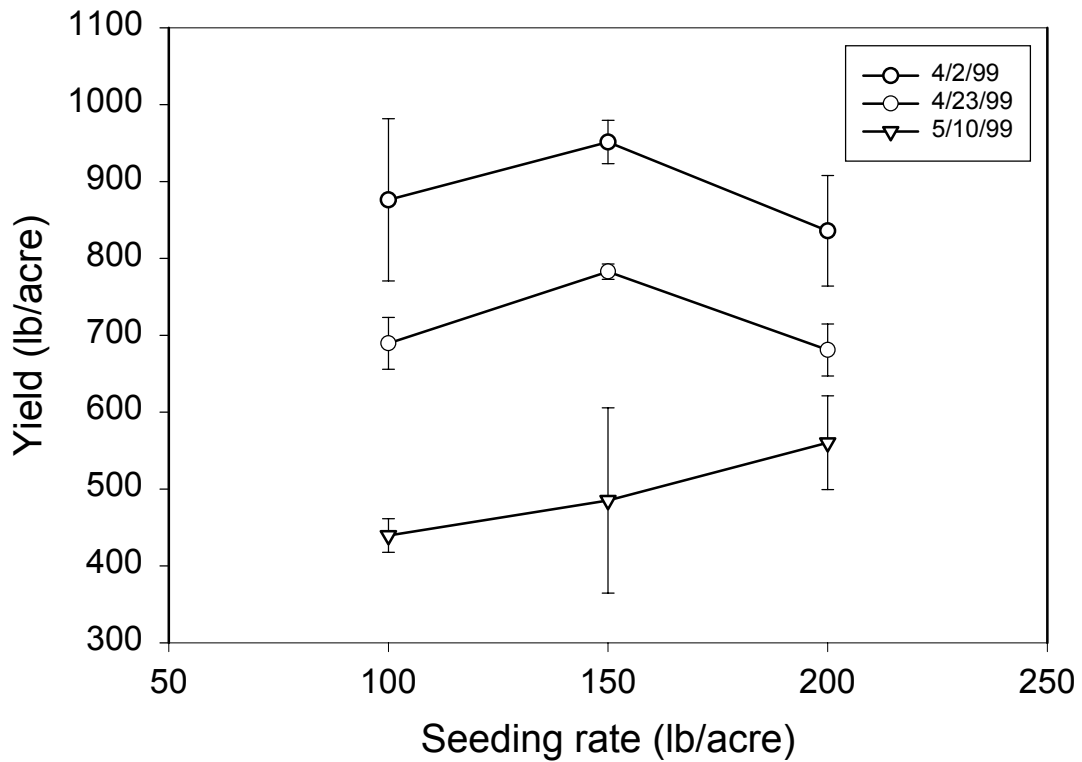


Figure 1. Yield response of Belara to seeding rate at the Helix, Oregon site for three seeding dates in 1999. The error bars on the graph represent ± 1.0 STD

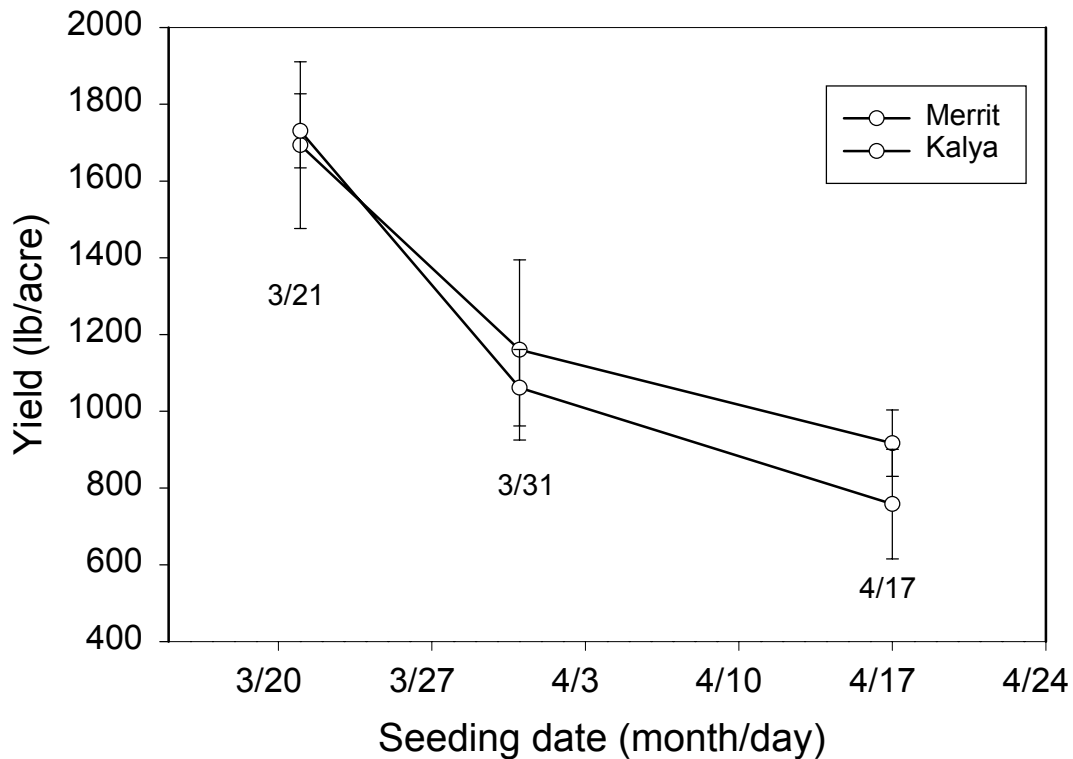


Figure 2. Yield response of lupin varieties Merrit and Kalya to seeding date in 2000 at the Pendleton, Oregon, site. The error bars on the graph represent ± 1.0 STD.

Seeding Date Effects on Yield, Seed Quality and Water Use Trial in 2000

As in the 1999 trials, significant decreases in yield were seen with delayed seeding in the 2000 trials at Pendleton (Table 3, Figure 2). Delayed seeding not only resulted in decreased yields, but also resulted in lower protein content (Figure 3). This effect was presumably due to the decline of water stored in the soil and the warmer and drier conditions to which maturing plants were exposed. High correlations between the amount of water stored in 3-ft soil profiles at seeding and yield and protein content were found ($R^2 = 0.9$). When the seeding date was delayed, the soil stored water decreased steadily due to the soil surface evaporation, even without a crop growing (Figure

4). Therefore, late-planted lupin had less available water in the soil profile and used less spring rainfall (Table 3). The late-planted lupin risked encountering terminal water and heat stress, thereby reducing yield.

In contrast, early seeded lupin used more spring rain and available water in the soil profile and produced much higher yields than the late-seeded lupin (Table 3). The early seeded lupin also had a higher water use efficiency (WUE) than late-seeded. Both Merrit and Kalya used 1 in of water to produce 126-127 lb per acre of seed when seeded on 21 March, but only produced 71-87 lb per acre of seed when seeded on 17 April. No difference in water use and water use efficiency was found between the two varieties.

Table 3. Soil stored water, rainfall, yield, and water use efficiency (WUE) at the Pendleton, Oregon, site in 2000 for two varieties of lupin and three seeding dates.

Variety	Seeding date (m/d)	Initial soil water (in)	Residual soil water (in)	Rainfall (in)	Total water used (in)	Yield (lb/acre)	WUE (lb/in)
Merrit	3/21	12.4	3.9	4.9	13.4	1693.5	126.4
	3/31	11.4	4.0	4.2	11.6	1159.8	100.0
	4/17	10.6	4.0	3.9	10.5	916.7	87.3
Kalya	3/21	12.4	3.7	4.9	13.6	1730.7	127.3
	3/31	11.8	4.0	4.2	12.0	1061.4	88.5
	4/17	10.4	3.6	3.9	10.7	758.0	70.8

Weed Control Experiment in 1999 and 2000

No lupin injury was evident from the herbicide treatments in 1999. Treatments containing Sencor showed slight, visible injury at Pendleton, but did not adversely affect lupin seed yield. Weed control was fair to good depending on herbicide treatment. Better growth and vigor were

observed at the Condon site compared to the Lexington site, which facilitated improved control of Russian thistle (Table 4).

Preplant, surface-applied Sonalan treatments generally provided more effective weed control than did Prowl treatments. Granular Sonalan appeared to provide slightly better weed control than the liquid

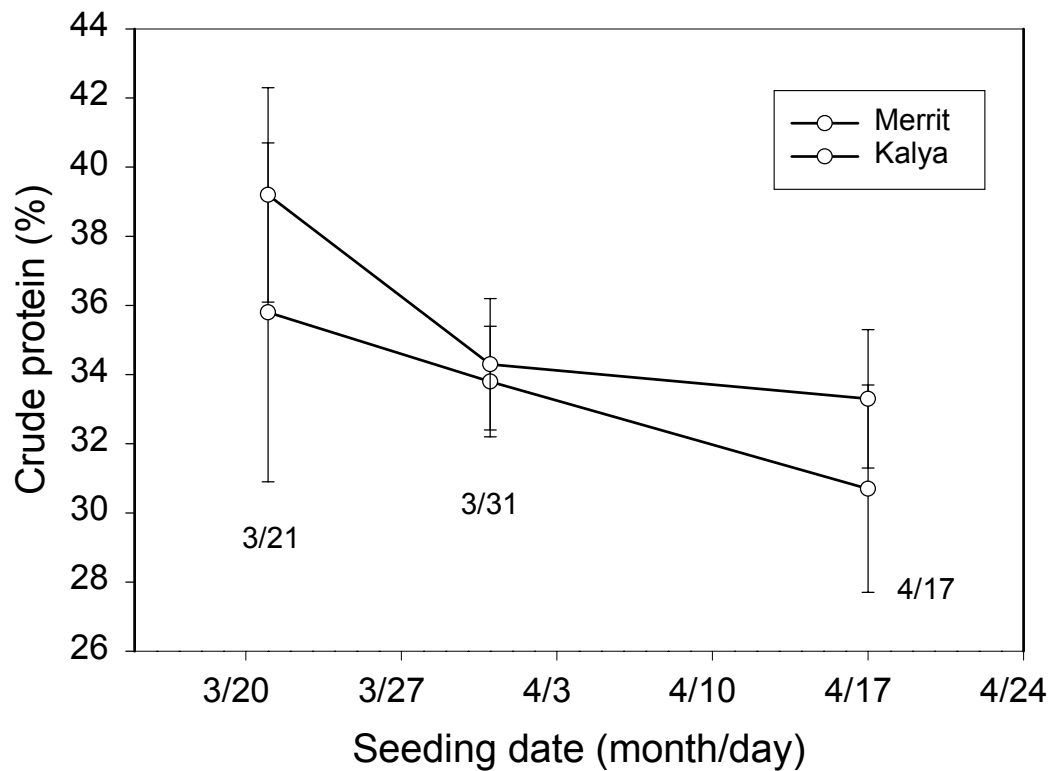


Figure 3. Protein content response of lupin grain to seeding date at the Pendleton, Oregon, site. The error bars on the graphs represent ± 1.0 STD

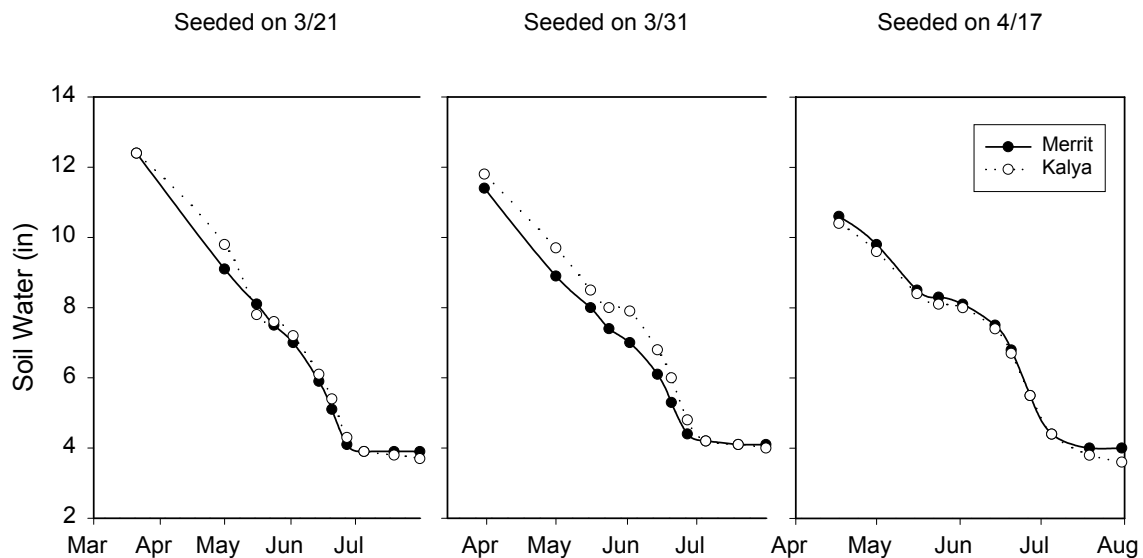


Figure 4. Changes of water stored in 3ft. soil profiles of lupin plots seeded on 3 different dates in 2000 at the Pendleton site

Table 4. Russian thistle control in direct-seeded lupin at Condon and Lexington, Oregon, 1999.

Treatment	Timing	Condon site			Lexington site		
		Lupin injury	Russian thistle control	Lupin yield	Lupin injury	Russian thistle control	Lupin Yield
		6/30/99	8/19/99	8/19/99	6/29/99	8/12/99	8/12/99
		----- % -----		lb/acre	----- % -----		lb/acre
Check		0	0	400	0	0	41
Prowl	PP [†]	0	78	540	0	20	35
Sonalan EC	PP	0	86	500	0	40	62
Sonalan G	PP	0	85	550	0	35	56
Prowl + Sencor	PP	0	76	420	0	23	46
Sonalan G + Sencor	PP	0	90	480	0	49	82
Prowl/Sencor	PP/PRE	0	84	510	0	13	30
Sonalan EC/Sencor	PP/PRE	0	85	370	0	50	80
Sonalan G/Sencor	PP/PRE	0	84	490	0	50	58
LSD (0.05)			14			21	

† PP = Preplant, PRE = Preemergence.

Table 5. Tarweed fiddleneck control in direct-seeded lupin at the Pendleton site in 2000.

Treatment	Timing	Pendleton site		
		Lupin injury	Tarweed control	Lupin yield
		6/2/00	6/2/00	7/28/00
		----- % -----		lb/acre
Check		0	0	1270
Sonalan EC	PP [†]	0	62	1180
Sonalan G	PP	0	80	1340
Sonalan G + Sencor	PP	6	83	1510
Sonalan EC/Sencor	PP/PRE	5	78	1470
Sonalan G/Sencor	PP/PRE	3	90	1580
LSD (0.05)		3	45	

† PP = Preplant, PRE = Preemergence.

formulation in the direct-seed system (Table 5). Inclusion of Sencor to treatments improved control of Russian thistle at the Lexington site.

Conclusions

When seeded before 1 April, all tested lupin varieties performed well at high and low rainfall sites at Pendleton and Moro under conventional tillage. Narrow-leaf lupins also yielded well in the 16-in rainfall zone at Helix and Pendleton under direct seeding when seeded before 2 April. However, narrow-leaf lupins did not produce acceptable yields at the Lexington and Condon sites at any seeding date due to drought in 1999. Further research is needed to test the narrow-leaf lupin varieties in those regions in normal rainfall years.

Lupin yield and protein content decreased with delayed seeding date, apparently because late-seeded lupins were not able to use spring rainfall and soil stored water effectively. Moisture was lost due to surface evaporation, and late-seeded plants were exposed to drought and heat stress during late growing stages. Consequently, early seeding of lupin resulted in higher water use efficiency than late-seeded lupin.

The varieties Merrit and Kalya have a potential to yield over 1,700 lb/acre in high rainfall regions in eastern Oregon if seeded early in March, while Belara tended to yield better than other varieties in low rainfall regions.

Preplant, surface-applied Sonalan treatments generally provided more effective weed control than did Prowl treatments. Granular Sonalan appeared to provide slightly better weed control than the liquid formulation in the direct-seed system. Inclusion of Sencor to treatments improved control of Russian thistle at the Lexington site.

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Acknowledgements

The authors thank Wallace Cowling of University of Western Australia for supplying seeds. We also thank Clinton Reeder (Helix, OR), Chris Rauch (Lexington, OR), and Van Rietmann (Condon, OR) for donation of land for on-farm trials, and Urbana Laboratories for providing the inoculant. We also want to thank Karl Rhinhart, Erling Jacobsen, Greg Harris, Devesh Singh, and Darrin Walenta for their help in planting, harvesting, and herbicide applications. This research was partially supported by STEEP.